National Cooperative Highway Research Program

Fiscal Year 2007 May 2006

Announcement of Research Projects

The annual "Announcement of Research Projects" is no longer mailed to individuals. Instead, e-mail notification is made. Recipients are encouraged to share this announcement with colleagues.

The **National Cooperative Highway Research Program** (NCHRP) is supported on a continuing basis by funds from participating member departments of the American Association of State Highway and Transportation Officials (AASHTO), with the cooperation and support of the Federal Highway Administration, U.S. Department of Transportation. The NCHRP is administered by the National Research Council's Transportation Research Board (TRB). The NCHRP is an **applied contract** research program totally committed to providing timely solutions to **operational problems** facing highway and transportation engineers and administrators.

Each year, AASHTO refers a research program to the TRB consisting of high-priority problems for which solutions are urgently required by the states. The AASHTO program for FY 2007 is expected to include 20 continuations, 33 new projects, and 4 projects contingent on additional funds becoming available.

This announcement contains preliminary descriptions of only those new projects expected to be advertised for competitive proposals. Detailed Project Statements (i.e., Requests for Proposals) for these new projects will be developed beginning in August 2006.

Please note that NCHRP Research Project Statements for soliciting proposals are available only on the World Wide Web. Project Statements are not mailed. Those who have an interest in receiving Research Project Statements must periodically browse the NCHRP World Wide Web site or register on the website (http://trb.org/nchrp) if you have not already done so. Upon registration, you will receive an e-mail notification of every Project Statement posting and an e-mail notification of new anticipated projects in future years.

Because NCHRP projects seek practical remedies for operational problems, it is emphasized that proposals not evidencing strong capability gained through extensive successful experiences in the relevant problem area stand little chance of being selected. Consequently, any agency interested in submitting a proposal should first make a frank, thorough self-appraisal to determine whether it possesses the capability and experience necessary to ensure successful completion of the project. The specifications for preparing proposals are quite strict and are set forth in the brochure entitled *Information and Instructions for Preparing Proposals*. **Proposals will be rejected if they are not prepared in strict conformance with the section entitled "Instructions for Preparing and Submitting Proposals."** The brochure is available on the Internet at the website referenced above.

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IMPORTANT NOTICE

Potential proposers should understand clearly that the research program described herein is tentative. The final program will depend on the level of funding available from the Federal-aid apportionments for FY 2007. Meanwhile, to ensure that research contracts can be executed as soon as possible after the beginning of the fiscal year, the NCHRP is proceeding with the customary sequence of events through the point of agency selection for all projects. The first round of detailed project statements will be available in August and September 2006; proposals will be due in October and November 2006, and agency selections will be made in November and December 2006. This places the risk of incurring proposal costs at the election of the research agencies. Beyond the point of selecting agencies, all activity relative to the FY 2007 program will cease until the funding authorization is known. These circumstances of uncertainty are beyond NCHRP control and are covered here so that potential proposers will be aware of the risk inherent in electing to propose on tentative projects.

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

National Cooperative Highway Research Program
Projects in the Fiscal Year 2007 Program

♦ **Project 03-65A**
Update of Roundabouts: Informational Guide

Research Field:	Design
Source:	AASHTO Standing Committee on Highway Traffic Safety
Allocation:	$200,000 (plus $150,000 from the FHWA)
NCHRP Staff:	B. Ray Derr

Many developments and studies have taken place since the publication of FHWA's *Roundabouts: An Informational Guide*. The findings and ongoing research (especially the NCHRP roundabout study) will enhance guidelines on operational analysis, design characteristics, and safety analysis of roundabouts. Considering that the guide has become an authoritative national publication, it would be of great benefit to update this guide and incorporate all findings after critically reviewing available and ongoing information and knowledge. Furthermore, incorporating new research on other users will contribute noticeably to improving and strengthening the practice for pedestrians, bicyclists, and users with special needs (visual and other physical impairments). Some of the items worth revising are as follows: geometric design (including triple-lane roundabouts), intersection sight distance, speed estimations, lane markings, signing, and other traffic control devices, construction and maintenance, safer accommodations of pedestrians, safety evaluation, access management considerations, applications at ramp terminals or interchanges, and mini-roundabouts.

The objective is to update and enhance the FHWA publication, *Roundabouts: An Informational Guide*, FHWA-RD-00-067 for continued use as a national reference and for the development of state and local policies and practices. The guide should include material for educating the public.

The content of the update should incorporate all new findings in all area of roundabout practices including: policy considerations, planning, traffic analysis procedures, safety findings and analysis procedures, geometric design (including all new findings on curvature, cross sections, intersection sight distances, and accommodation of larger vehicles), pedestrian and bicycle treatments, special considerations for interchange applications and access management, traffic control devices, construction considerations and maintenance of traffic, and network considerations and traffic simulation.

♦ **Project 08-60**
Risk Management Manual for Methods and Tools to Control Project Cost Escalation

Research Field:	Transportation Planning
Source:	AASHTO Standing Committee on Planning
Allocation:	$200,000
NCHRP Staff:	Ronald D. McCready

Project cost escalation from planning to construction is a fundamental problem facing the transportation industry. A current project, NCHRP 8-49, is focusing on the issue of cost escalation and developing a guidebook on highway cost estimating management and project cost estimating aimed at achieving greater consistency and accuracy between long-range transportation planning, priority programming, and preconstruction estimates. This project has identified risk management as one of the primary strategies to help control cost escalation.

One critical factor causing cost escalation related to risk management is "inconsistent application of contingencies." Contingency funds are typically meant to cover a variety of possible events and problems that are not specifically identified or to account for a lack of project definition during the preparation of early cost estimates. In other words, contingency funds cover project risks that may occur as a result of uncertainties related to all aspects of projects. NCHRP 8-49 and NCRHP 20-7/152 have found that inconsistent application of contingencies is prevalent in most state highway agencies and there is a lack of national guidance on the topic. Further, the risks that drive cost contingencies, including environmental permitting, right of way, and utilities, are not being addressed adequately in current cost estimating and cost estimating management processes.

The 8-49 Guidebook identifies eight global strategies that address the factors that lead to cost escalation. The “risk strategy” is one of the most important. The risk strategy is to *identify risks, quantify their impact on cost, and take actions to mitigate the impact of risks when controlling costs*. This strategy, while addressing the factor “inconsistent application of contingencies,” also addresses many other important cost escalation factors such as project schedule changes, engineering and construction complexities, scope creep, market conditions, and unforeseen conditions. Because the current scope of the NCHRP 8-49 study develops multiple strategies for controlling cost escalation, it does not allow for in-depth treatment of methods and tools necessary to implement a specific strategy such as the risk strategy. There is a need for in-depth treatment of procedures and the development of a detailed “how to” manual for practitioners to deal with risk management applications.

The objective of the proposed research is to further refine in a procedures manual format, risk-related methods and tools and provide more specific guidance on how to implement the risk strategy into practice. The tasks would include: updating risk management current practice review and expanding it to non-transportation sectors; conducting rigorous case studies of risk-related methods and tools in the 8-49 Guidebook and other potential methods and tools specific to risk; developing methods and tools in a comprehensive plain language format; and providing a “how to” approach to implementing risk-based methods and tools.

♦ **Project 08-61**

Travel Estimation Techniques and Parameters for Transportation Planning (aka NCHRP Report 365 Update)

Research Field:	Transportation Planning
Source:	New York
Allocation:	$550,000
NCHRP Staff:	Ronald D. McCready

In 1978, the Transportation Research Board published NCHRP Report 187, *Quick-Response Urban Travel Estimation Techniques and Transferable Parameters*. This report described transferable parameters, factors and manual techniques for doing simple planning analysis. The report and its default data were widely used and carried the transportation planning profession for almost 20 years. In 1998, drawing upon several newer data sources including the 1990 Census and National Personal Household Travel Survey, an update to NCHRP 187 was published in the form of NCHRP Report 365, *Travel Estimation Techniques for Urban Planning*.

Since NCHRP 365 has been published, a whirlwind of changes affecting the size, scope, and shape of the transportation planning landscape have occurred. Planning concerns have grown beyond “urban” to include rural, statewide, and special use lands. The scope has broadened into special populations (tribal, immigrant, old, young, etc.); specific issues (safety, air quality, environment, etc.); and shifting time frames ranging from current estimates to multiyear forecasts. The shape of the planning industry itself has changed with the evolution of a variety of newly developed tools. Simulation, activity-based modeling and econometric land use models are just a few of the planning tools that are moving into common practice. Complementing all of this, the data sources from which NCHRP 365 was built are now old and have been replaced. In fact, since NCHRP 365 was published, the National passenger travel survey was updated twice (1995 and 2001) providing for a quantum leap in terms of the data available for transportation planning.

Not withstanding how one may characterize the changes that have occurred since NCHRP 365 was developed, the point remains that this resource is in dire need of being updated to reflect the planning needs of today and the next 10 years.

The current project will build upon NCHRP 187 and 365 to address the changes and current day planning practices. It will expand upon the prior documents to cover the current and emerging planning methodologies used in urban, rural, and state situations. It will also incorporate a greater emphasis across modes, including but not limited to freight and passenger travel. Given the completion of two national long-distance travel surveys since NCHRP 365 was published long-distance travel will also be added.

The research will draw upon all relevant and available data. Not only have the national data sets been updated but a critical mass of household travel surveys and other relevant data has been collected at the local and regional levels.

For example, the New York State DOT was part of a Nationwide Personal Travel Survey expanded sample add-on in both 1995 and 2001. Of note is its significant research in transferability of travel parameters for the range in size of its metropolitan and non-metropolitan areas across the state. Where possible, these and other data and analysis results for short- and long-term travel need to be incorporated into the document.

Other areas to address include new chapters on model calibration/validation practices, statewide model development, rural model development, and the data needs.

Besides expanding on the technical content within the document, this research must consider electronic delivery mechanisms (i.e., web-based) that can be continuously updated as new/better information becomes available.

This is a high priority issue supported by many state DOTs, Metropolitan Planning Organizations (MPOs), FHWA, and a host of TRB committees. Completion of this research is very time sensitive given that much of the source data has just been released. The data provided in NCHRP 365 and 187 is not only in widespread use by the large MPOs, it is the main and sometimes only data resource for small- to medium-sized areas MPOs that must maintain travel forecast models. These agencies often do not have the budget to conduct new travel surveys or collect original data. Anticipated products from this research will be used directly by planners at MPOs and state DOTs and their agents responsible for developing travel forecasting models and plans.

The AASHTO Standing Committee on Research recognized that Problem No. 2007-B-09 was similarly written and should be considered as well.

♦ **Project 08-62**

Implementing Transportation System Performance Management Programs—Insight from Practitioners

Research Field: Transportation Planning
Source: California
Allocation: $200,000
NCHRP Staff: Ronald D. McCready

This proposal is to support the development and implementation of transportation system performance measurement programs. Many states have begun the process of developing such programs. To date, research in this arena has primarily focused on establishing general frameworks and guidelines to serve as a basis from which performance programs may be established and expanded. Such research provides examples of the tools and institutional frameworks that are necessary for the construction of performance measurement programs. Missing from the literature are in-depth examples of how performance measurement programs have been and are being integrated into strategic planning processes. Tools alone are not sufficient for program implementation. There is a need for in-depth analyses of exactly how performance measurement programs are implemented and integrated into the decision-making processes that govern the way departments of transportation in the U.S. deliver services to their customers. Such research will build on existing research, providing necessary insight into implementation by not only identifying techniques and strategies that have been used to implement performance measurement programs, but also by describing in detail how and why specific techniques and strategies were used and the results of their usage.

The results of the proposed research could be used by transportation planning agencies at all levels to assist them in implementing performance management programs, which, in turn, would advance strategic planning and improve investment decisions.

The majority of research for developing transportation system performance management programs highlights the tools, frameworks, guidelines, and so on necessary for performance program creation and implementation. No comprehensive investigation of how tools can be or are used to implement programs is available.

The objective of this proposal is to assist transportation professionals as they strive to implement performance management programs by providing in-depth examples of how performance measurement programs have been and are being integrated into strategic planning processes in a sample of states across the U.S.

The final product should be a handbook that contains a description of the performance management program implementation processes followed by a sampling of states across the U.S. The handbook should also contain analyses of implementation strategies and techniques for both those that were successful and those that were not.

Scarce transportation resources and the need for improved decision support tools are two main justifications for the development of performance management programs. The main justification for this research is that although many states are integrating individual performance criteria into their decision-making processes, few, if any, have been successful in the comprehensive implementation of performance management programs required for strategic planning. While many are knowledgeable concerning the available tools—performance measures, management structures, reporting methods, and so on—they would benefit from the insight provided by others who have experienced the implementation process.

Implementation and integration of transportation system performance management programs is essential if public transportation providers are to make the transition to more business-like operations. Without the comprehensive implementation of performance management programs improved decision making becomes increasingly difficult. It is impossible to make decisions among multiple investments without an overall understanding of the possible options and outcomes. Performance management can begin to provide such understanding, but only if it is comprehensively, yet strategically implemented.

♦ Project 08-63
Review of Canadian (and Mexican) Experience with Large Commercial Motor Vehicles

Research Field:	Transportation Planning
Source:	Federal Highway Administration
Allocation:	$100,000
NCHRP Staff:	Christopher J. Hedges

Pressure is building across the U.S. to allow heavier vehicles on the Interstate System. Efforts to pilot test expanded operations of heavier commercial vehicles, as recommended by TRB in 2002, have confronted existing federal weight limits and an active popular opposition to any increase in commercial vehicle weights. Canada offers a readily available source of data and insight into the effects of legally permitted, contemporary vehicle operations at a weight level well beyond those permitted in the U.S. today.

In addition, by 2009 at the latest, the U.S. DOT will want to be in a position to advise the Administration and Congress whether changes to the current federal size and weight provisions should be effected. Evidence from studies such as this one will help shape the debate of possible weight and size allowance changes that may be anticipated.

Both Canada and Mexico allow commercial motor vehicles (CMVs) to operate on national highways at axle and gross vehicle weights significantly above those in the United States. Canadian provinces individually may also authorize their own heavier vehicle weights and combination provisions. Because of an increasing demand in the U.S. for heavier loads on the Interstate system, in some cases to accommodate comparable vehicles to those allowed in Canada, research is proposed to evaluate the:

- Management and regulatory procedures used by Canadian governments for these heavier vehicle movements.
- Scope of operation.
- Accumulated effect on the preservation and maintenance of the highway infrastructure.
- Effect on road safety.
- Enhancement of shipper productivity.
- Influence on traffic mobility.

The objective of this study is to evaluate the Canadian motor carrier experience to learn more of the varied effects on road infrastructure that result with the continuous movement of heavier commercial motor vehicles; identify special issues relating directly to these heavier movements; determine how Canadian jurisdictions dealt with damage done by them; identify what kind of additional maintenance was required and how financed; see if road safety was adversely affected; and consider how the Canadian experience overall might be applied to commercial vehicle operations and their regulation in the U.S.

Note: The AASHTO Standing Committee on Research requested that the study include a review of Mexican truck size and weight regulations.

♦ **Project 08-64**
Cost Allocation Methods for Shared-Use Passenger and Freight Rail Operations

Research Field:	Transportation Planning
Source:	AASHTO Standing Committee on Rail Transportation
Allocation:	$500,000
NCHRP Staff:	Ronald D. McCready

The United States is facing increasing congestion problems on the nation's highways, as well as growing infrastructure challenges on the national rail system caused by increasing traffic and heavier rail cars. Record gasoline prices are increasing public demand for efficient, energy conservative transportation alternatives. Faced with these problems, and an increasing emphasis on multimodal planning under Federal ISTEA and TEA 21 transportation legislation, state interest in intercity passenger and commuter rail development has grown significantly in recent years. Thirteen states currently support Amtrak service and some 38 states have developed or participated in the development of future plans for enhanced intercity passenger rail service throughout the country. There are an ever-growing number of commuter transit operations operating on lines of various ownership configurations (e.g., freight railroad, county, city, state, authorities, etc.). The AASHTO report "Intercity Passenger Rail Transportation" (January 2003) documents $17 billion in state-defined infrastructure and equipment needs over six years and another $43 billion in needs over the next two decades. Eighty percent of these needs involve investments on privately owned freight corridors. A number of these state plans are moving toward implementation with the completion of NEPA-required environmental assessments and environmental impact statements along with preliminary engineering.

Congress has responded with proposals for federal funding of intercity passenger rail service such as the RIDE 21 Program. This proposal provides $12 billion in tax credit bonding authority to states for infrastructure and equipment and was reported unanimously out of the House Transportation and Infrastructure Committee in the 108th Congress. This and other similar legislative proposals call for states and underlying freight railroads to reach "arms length" agreements regarding access, the proper level of infrastructure improvements, maintenance costs, and other issues before federal project funding is provided.

At this point in time, there is no generally accepted methodology for determining how to equitably address these issues in a manner that protects the public interest while at the same time providing private freight railroads a reasonable incentive for entering into such an agreement. This sets the stage for a long and often frustrating negotiating process that can significantly delay project implementation.

The objective of this research is to develop an agreed-upon methodology for determining the proper level of publicly funded infrastructure improvements and for allocating maintenance and other costs for passenger and freight rail services operating on shared-use corridors.

This research will require a multi-disciplinary team with backgrounds in economics, business, public planning and policy, and freight and passenger rail engineering, operations and finance. Such a team will require both academic backgrounds and commercial experience with the freight and passenger rail industry.

The study will need to have the active involvement of the major stakeholders including the states, freight railroads, Amtrak, commuter railroads, and others.

In addition to developing principles and methodologies for addressing the above issues, one or more case studies will be desirable to demonstrate their application. The case studies should be designed to cover the spectrum of geographic areas, freight densities, passenger service operating speeds, infrastructure improvement programs and ownership-configurations.

The study should address at a minimum, the development and application of the cost-allocation methodology to state-supported intercity rail service on private freight railroads.

In conducting a national study to develop such a methodology, there are a number of issues that must be addressed:

Development of a public policy and economic rationale: What are the underlying economic, business and public policy principles that should be observed in developing public-private partnerships for passenger, freight and commuter rail development on shared-use rail systems? Does the existing statutory "right of access" provided by Amtrak provide an adequate institutional framework for successful private partnerships? How will issues of indemnification and liability insurance be addressed? What changes may be needed (legislative or otherwise)?

Publicly funded infrastructure: With the introduction or expansion of state-supported passenger rail service on privately owned rail corridors, what amount of infrastructure will be required? This includes: track and tie improvements, new shared-use or dedicated track in freight-owned rights-of-way, passing sidings, crossovers, signals, highway grade crossing improvements and warning devices, culverts, bridges, and drainage improvements. Will these improvements be designed for current capacity needs, future capacity needs, or both? If an incremental improvement for passenger rail service, such as a new parallel track, provides significant capacity benefits, should freight rail cost sharing be expected or otherwise accounted for? How will operational benefits to the freight railroad be accounted for? What benefits should flow to freight railroads as an incentive to participate in public-private partnerships to provide passenger or commuter rail service?

Operating and maintenance costs: The introduction or expansion of state-supported passenger rail service will involve incremental track maintenance costs associated with moving speed classifications from Class 3 to Classes 4, 5, and 6. How should these incremental costs be allocated? Likewise, freight railroads are increasingly operating heavier cars and locomotive weights for all uses. How should associated incremental structure and signal maintenance costs be allocated? Freight railroads may incur other incremental costs such as dispatch costs, accounting and administrative costs, and management and liaison costs. How should these costs be calculated and allocated?

Deliverables should include: recommended cost allocation methodology for infrastructure improvements and maintenance costs; analysis and recommendations regarding the public policy and economic rationale for the recommended cost allocation methodology; and one or more case study applications of the recommended methodology demonstrating is applicability.

As noted above, this effort should address at a minimum, the development and application of a cost allocation methodology to state-supported intercity rail service on private freight railroads as a "Phase I Study." If funding is limited under this Phase I Study, it is proposed that future phases be funded to address additional related topics: (1) The application of the cost allocation methodology to publicly supported commuter rail transit services operating on private freight railroads, (2) The application of the cost allocation methodology to the introduction of freight operations on publicly owned commuter railroad corridors, and (3) Other topics as identified in the Phase I work. Phase I work should include the development of a scope of work for these areas as appropriate.

The concept of passenger and freight operations co-existing in shared-use corridors is central to the further development of intercity passenger rail service in the United States. All current Amtrak service is on shared-use corridors. Virtually all future plans for enhanced intercity passenger rail service developed by states are based on the shared-use corridor concept.

As documented in AASHTO's report, "Intercity Passenger Rail Transportation," the great majority of all state-proposed passenger rail improvements are on shared-use corridors generally with top speeds of up to 110 mph. This report documents twenty-year infrastructure and equipment needs of over $60 billion. This planning has proceeded and is continuing to proceed without a methodology that assures that estimated capital and maintenance-related operating costs are properly being allocated between the public and private sectors.

This is not just a technical question, but also a major public policy question. As discussed earlier, federal passenger rail funding legislation is being proposed with requirements for agreements between states and freight railroads on shared-use corridors, but there is no agreed-upon cost-allocation methodology as a framework for developing these agreements.

States throughout the country are already proceeding with state-funded passenger rail projects on shared-use corridors, and they need a methodology to address these cost allocation issues now. States have already found by experience that negotiations with freight railroads on shared-use corridors are complicated and time consuming—largely because there is no methodological framework for developing a cost-sharing agreement which both parties would benefit from.

♦ Project 09-43
Mix Design Practices for Warm Mix Asphalt Technologies

Research Field:	Materials and Construction
Source:	AASHTO Highway Subcommittee on Materials, Ohio
Allocation:	$500,000
NCHRP Staff:	Edward T. Harrigan

Traditionally, hot mix asphalt (HMA) has been produced in either batch or drum plants at a discharge temperature of between 280° and 320° F. It has been necessary to use these elevated temperatures in order to dry the aggregate, coat it with the asphalt binder, and achieve the desired workability. Mixing temperatures are set according to local practice or AASHTO Test Procedure T-316. Higher temperatures are often associated with the use of polymer modified binders. While the current state of production and paving has been shown to be environmentally sound and not harmful to workers, reducing HMA production and placement temperature could bring several cost, environmental, and performance benefits. The industry is embarking on a goal of reducing production temperatures by 50° F or more within the next decade.

Reduced production and paving temperatures would have beneficial environmental effects. There would be a decrease in the energy required to make HMA. Projections suggest that the recent increases in petroleum prices will persist well into the future. Reduced temperatures could also have a profound influence in reducing emissions and odors from plants, thereby further improving environmental benefits and public opinion. Cooler temperatures would improve the working conditions at the paving site.

In terms of performance, the technologies that allow reduced production temperatures may have positive impacts. Some of the original applications of these included enhanced compaction, a key parameter in performance. Because the technologies improve the workability of the mix, they should make in-place density easier to achieve. The majority of aging in an asphalt mixture takes place during production when it is exposed to elevated temperatures. By reducing temperature, less oxidative hardening will take place, which should reduce the mixture's susceptibility to cracking by improving its flexibility. Reduced hardening does increase the potential for permanent deformation, and strategies such as the use of harder grade binders and stone skeleton mixes need to be developed to address this.

The Europeans have already begun using warm mix asphalt (WMA) technologies to lower mix temperatures, and the results have been very promising. Much of the incentive in Europe are the goals to reduce temperatures in mastic and gussasphalt mixes (not used in the U.S.) and the reduction of greenhouse gases in response to European Union mandates. In the U.S., these technologies are being tried with an eye to the future and the hope that the promising benefits they bring can be realized.

There are far-reaching implications for WMA technology. The information available from the manufacturers and materials suppliers so far indicate energy savings on the order of 30 percent, with a reduction in CO_2 emissions of 30 percent. The harmful fumes in the vicinity of workers are below the detection limits, and there is a 50 to 60 percent decrease in the generation of dust. The ability to improve the environmental friendliness of asphalt mixtures creates opportunities to expand production. For instance, by lowering the paving and compaction temperature, the ability to perform late-season paving is enhanced. Because the mix starts at a lower temperature, it does not cool off as rapidly, allowing a greater time to compact the mat. Another benefit may be in the form of paving in ozone-nonattainment areas. Because of the lower production temperatures, it may be possible to run plants during more daylight hours in these regions.

While the technologies available to reduce HMA production and placement temperatures offer promising results, much needs to be learned concerning mix design and performance testing of WMA mixes. Because of the variety of proprietary products and processes involved, the conventional methods of mix design may not be appropriate. For instance, the establishment of mix and compaction temperatures would need to be investigated because of the reduced field temperatures. Because of these reduced temperatures, aging procedures in the laboratory need to be reviewed and adjusted, if necessary. The increased workability should result in easier compaction, and thus, the laboratory effort might need to be refined.

The objective of this project is to develop a performance-based mix design procedure for warm mix asphalt in the form of a manual of practice for use by engineers and technicians in the public and private sectors. It is possible that the results of NCHRP Project 9-33 will also be appropriate for WMA with minor modifications. This research effort should build upon the NCHRP 9-33 results as much as possible. In the end, because of the proprietary nature of the methods employed, having a suite of performance tests is even more important in determining the adequacy of the mixes for field applications.

The following tasks are anticipated to accomplish this objective: (1) conduct a review of WMA technology; (2) develop a volumetric mix design, including the identification of appropriate mixing and compaction temperatures, aging protocols, and laboratory compaction effort; (3) select appropriate test protocols and criteria for rutting, fatigue cracking, thermal cracking, and moisture sensitivity; (4) incorporate the results of Tasks 2 and 3 in a new or adapted mix design method; and (5) document the research findings in the form of a draft AASHTO recommended practice.

♦ Project 09-44
Fatigue Characteristics of Full-Scale Long-Life Asphalt Pavements

Research Field:	Materials and Construction
Source:	AASHTO Highway Subcommittee on Materials, Ohio
Allocation:	$300,000
NCHRP Staff:	Edward T. Harrigan

Asphalt pavements that have fatigue cracking that propagates from the bottom of the asphalt layer and comes up to the surface require some of the most invasive rehabilitation techniques. Commonly, the required rehabilitation varies between cutting and patching the affected asphalt in the wheelpaths to removing and replacing the hot mix asphalt (HMA) surface and any other weakened pavement layer. Usually, either of these procedures requires an additional thickness of asphalt to preclude future fatigue distress. Classical bottom-up fatigue cracking occurs when wheel loads repeatedly cause large enough tensile strains to initiate cracking that eventually propagates all the way through the HMA layer. This form of distress has most often been related to inadequate structural design, soft base materials or subgrades, and overly stiff asphalt mixtures.

Well-performing HMA pavements have material and structural attributes that preclude fatigue cracking coming up through the structure. They have enough HMA thickness to reduce the tensile strain at the bottom of the asphalt layer so that cracking cannot start there. The reduction of strain in a bending structural member is a function of its depth cubed so that small increases in thickness have a dramatic effect in the reducing tensile strain. Long-life asphalt pavements have a sound foundation to support the structure and aid construction. Materials below the HMA that are susceptible to long periods of weakening may be stabilized in place, removed and replaced, or moved low enough in the pavement structure to significantly reduce the stresses. The asphalt mixture at the bottom of the pavement must be flexible enough to avoid cracking at low levels of tensile strain. However, the level of strain in an asphalt layer below which fatigue damage does not occur, also known as the endurance limit, has not been established for various pavements.

To date, a number of studies in the Netherlands, the United Kingdom, and the states of Washington and New Jersey have shown that thick asphalt pavements do not exhibit bottom-up fatigue cracking. These studies have concluded that pavements with HMA layers as thin as 160 mm do not fail in classic fatigue. While this strongly suggests that the endurance limit concept for HMA is correct, it does not answer the question of what tensile strain levels in existing pavements result in this type of performance. Identifying the design parameters that allow asphalt pavements to last for long periods of time will result in more efficient long-life pavement designs over designs that are overly conservative.

Endurance limits are recognized for other materials, such as steel. To paraphrase the definition given in the glossary at http://www.instron.com, the endurance limit is usually determined from a strain versus number of cycles to failure diagram and is equal to the strain corresponding to the asymptote of the locus of points corresponding to the fatigue life of a number of test specimens. In other words, below this strain, fatigue cracking will not occur. Defining this point for asphalt pavements will be of benefit to structural design because a practical limit in pavement thickness could be realized for HMA mixtures with different properties. For instance, it is well known that mixtures with greater flexibility due to higher asphalt contents have longer fatigue lives, and this would presumably translate to higher strain level for the endurance limit of pavements having these mixes.

The current state of pavement design does not recognize endurance limits for flexible pavements. Both the 1993 AASHTO pavement design guide and the upcoming mechanistic-empirical design guide, which is under review, result in ever increasing thickness for increasing traffic. To date, researchers have not attempted to quantify field strains in order to find an endurance limit for pavement sections. A few researchers such as Monismith and Carpenter have suggested that the endurance limit concept is consistent with the behavior of asphalt pavements, and they have gone as far as to suggest an approximate level of 70 microstrain as that limit. A limited amount of field validation of this concept is underway at the NCAT Test Track. However, field validation of this on long-lasting in-service pavements and more accelerated pavement test sites is needed.

The laboratory phase of this research is currently underway in NCHRP Project 9-38. To date, all indications are that the laboratory effort will be successful in identifying an endurance limit for hot mix asphalt. At this point, a field study needs to be conducted to ascertain the behavior of long-life asphalt pavements in the field.

The objective of this study is to prepare a detailed, statistically sound, and practical plan for a joint field-APT experiment that will (1) validate the concept of an endurance limit for flexible pavements, (2) establish the endurance limit for a wide variety of asphalt pavements, and (3) propose guidelines for the design of long-life flexible pavements.

The following tasks are anticipated to accomplish this objective: (1) identify field pavement sections and APT experiments that will provide sufficient performance, materials, and traffic data; (2) prepare a comprehensive plan, including a detailed budget and schedule, for the data collection, testing, and analysis needed to validate the concept of an endurance limit for flexible pavements; and (3) prepare a final report documenting the results of the project.

♦ Project 09-45
Development of Specification Criteria for Mineral Fines Used in HMA

Research Field:	Materials and Construction
Source:	AASHTO Highway Subcommittee on Materials
Allocation:	$500,000
NCHRP Staff:	Edward T. Harrigan

The mineral fines in hot mix asphalt (HMA) play an important role in the construction of HMA pavements and their performance. Very little attention was given to the study of mineral fines (often referred to as the minus 200 fraction) during the Strategic Highway Research Program although the Superpave mix design method does include a restriction on the dust to binder ratio. The experience of many in the field indicates that this ratio may be too restrictive and in some cases enhanced constructability and performance could be achieved with the use of additional fines as long as they are properly specified. The nature and quantity of mineral fines are especially important in stone matrix asphalt (SMA) mixes where they contribute significantly to compactability, permeability, and in-service pavement performance. The specification of mineral fines used in HMA is given less emphasis in the U.S. than in Europe where a number of different test methods and more restrictive criteria are often part of HMA specifications. Given the length of time since a major study was conducted on mineral fines and their importance to the performance of HMA and, in particular, SMA, a significant national study on the specification of mineral fines and their relationship with pavement performance is clearly warranted.

The objective of this study is to develop test procedures and specification criteria to characterize the performance of mineral fillers or mixtures of binder and mineral filler.

The following tasks are anticipated to accomplish this objective: (1) conduct a thorough review of (i) current practices within the United States on the specification and use of mineral fines and document problems in the field related to constructability or performance that can be related either in part or in full to mineral fillers and (ii) the nature and characterization of the physical properties of mineral fillers and mineral filler-asphalt binder mixtures as they relate to their behavior in HMA; (2) prepare detailed work plans for experiments to (i) develop the necessary test procedures, (ii) apply these test procedures to different mineral filler or mineral filler-binder combinations, and (iii) conduct a laboratory validation of the effectiveness of the test procedures with respect to their potential for improving the quality of HMA; (3) conduct the laboratory experiments developed in Task 2 and analyze the results to identify the most promising procedures; (4) if warranted by the results of Task 3, conduct the validation experiment developed in Task 2 with a suite of mineral fillers and binders representative of materials used in the field and associated with problems reported in the field, to include fly ash and fly ash/lime fillers and modified asphalt binders; and (5) prepare a final report that summarizes findings, draws conclusions, documents results, and presents (a) the recommended test procedures in AASHTO format, (b) recommended specification criteria and associated limits for each criteria, (c) the feasibility of implementing the recommended specification test procedure and criteria, and (d) the anticipated impact of the recommended specifications on the HMA industry.

♦ **Project 10-73**

Guide Specifications for the Design of Externally Bonded FRP Systems for Repair and Strengthening of Concrete Structures

Research Field:	Materials and Construction
Source:	AASHTO Highway Subcommittee on Bridges and Structures
Allocation:	$450,000
NCHRP Staff:	Amir N. Hanna

The techniques whereby fiber reinforced polymer (FRP) laminates are externally bonded to reinforced or prestressed concrete structural members are becoming more established as an alternative to traditional structural repair, strengthening, or rehabilitation methods. Extensive research has shown that external bonding of FRP laminates improves both short- and long-term flexural behavior of concrete members. In addition, research has shown that the capacity of concrete bents and columns can be increased through the use of FRP applications. Ongoing research is seeking to address the application of FRP materials in shear design. At present, many states are using FRP composites to repair and strengthen their concrete bridges. Throughout this process, structural designers have been hampered by the lack of suitable specifications for the design of these strengthening or repair methods.

At present, there are no AASHTO design specifications for bonded FRP repair or strengthening of concrete structures available to designers or bridge owners. The development of such specifications is critically needed; it will tend to standardize the design process, put the FRP repairs or strengthening of bridge structures on a firm engineering basis throughout the United States, further develop the usage of FRP materials, and make owners more comfortable with the overall design process.

The objective of this project is to develop a guide specification for the design application for FRP composite repairs or strengthening in the highway environment. The research agency shall develop the proposed specification in an AASHTO LRFD format suitable for use in the structural design and repair of highway bridges. The proposed document shall include design examples illustrating the use of the proposed Specification. The proposed document shall use the latest research, published design methodologies, and other pertinent information in developing the specification. It is further anticipated that the ACI guide specification for design and construction of externally bonded FRP systems will be an important reference in the specification development process.

♦ Project 13-03

Guidelines for Decision Making on the Use of Agency and Vendor Resources for Equipment Fleet Operations

Research Field:	Maintenance
Source:	AASHTO Highway Subcommittee on Maintenance
Allocation:	$300,000
NCHRP Staff:	Amir N. Hanna

Nearly all state departments of transportation (DOT) equipment fleets outsource some repairs or services. Reasons vary from cost effectiveness and/or lack of internal resources to political pressure to outsource/ privatize. DOT fleet managers and management personnel need a guidebook for objectively determining the most efficient and effective use of agency and vendor resources.

The objective of this research effort is to develop a guidebook that would document and describe the current and "best practice" fleet outsourcing and privatization practices at DOTs and related fleets, including concepts such as managed competitions (where agency employees compete against private-sector vendors to perform services) and having vendors collocated on DOT facilities to provide parts support and/or equipment maintenance. Also the guidebook should identify the critical cost and performance measures for stakeholders to examine in making initial determinations about the potential to save money or improve service through privatization or outsourcing.

> Note: The AASHTO Standing Committee on Research recommended that the scope of the project be expanded to incorporate issues relevant to establishing uniform preventive maintenance practices and procedures for DOT fleet equipment (Problem No. 2007-F-07).

♦ Project 15-37

Revision of the AASHTO Guide for the Development of Bicycle Facilities

Research Field:	Design
Source:	AASHTO Technical Committee on Non-Motorized Transport, AASHTO Technical Committee on Geometric Design
Allocation:	$250,000
NCHRP Staff:	Christopher J. Hedges

The AASHTO *Guide for the Development of Bicycle Facilities* has been put to widespread use by public agencies and consultants who are planning and designing bikeways, highways, and streets. The guide has been AASHTO's best seller for a number of years. Popularity of the guide has grown exponentially as more bikeway projects have been funded and developed since the passage of ISTEA in 1991. Despite its popularity and utility, the guide is lacking important information and much current information needs updating. In 2004, a small research project was funded through a NCHRP special projects program that included initial market research, interviews, and a literature review to determine the scope and content of the next edition of the AASHTO Bike Guide. That report recommended that nearly a hundred new items be added to the guide. Additionally, many materials currently in the guide need to incorporate changes from updated national manuals such as the MUTCD and the AASHTO Green Book, as well as pertinent research reports on specific bicycle topics. Because of the shortcomings of the guide, many current decisions affecting the planning and design of bicycle ways are not based on research, acknowledged practices, or the collective knowledge of professionals.

The revised guide will continue to have the same user groups as it had in the past. However, the expanded and updated version, as recommended in the recent research, will make the guide much more relevant to planners, project designers, and traffic engineers. Overall, an updated and revised guide will have offer more utility to all users because it will be more comprehensive.

The objective of the study is to revise and/or update all aspects of the current 1999 *Guide for the Development of Bicycle Facilities*. This revision should generally follow an outline prepared under NCHRP Project 20-7(187) which involves updating current information and adding additional guidance. The outline calls for new chapters on planning, bicycle operation and safety, maintenance, bicycle parking, and bicycle linkages to transit. Significant expansion of the guide is being called for within the existing chapters on shared roadways, bike lanes, and paths. Significant guidance is recommended for intersection design affecting all bikeway types, bicyclist performance attributes, and ADA compliance on shared-use paths.

Tasks involved in the development of the report include: review the recommendations of the special projects research report 20-7(187), review and consider state DOT and local design manuals holding discussions with DOTs where necessary, incorporate changes from updated national manuals such as the MUTCD and the AASHTO Green Book, review pertinent research reports on specific bicycle topics, and consider all of the recommended new topics identified in the outline established under 20-7(187). Close coordination with AASHTO committees will be essential throughout the study.

♦ Project 17-38
HSM Implementation and Training Materials

Research Field:	Traffic
Source:	AASHTO Standing Committee on Highway Traffic Safety
Allocation:	$400,000
NCHRP Staff:	Charles W. Niessner

The Transportation Research Board (TRB) has a ground-breaking initiative currently underway to develop a *Highway Safety Manual* (HSM). It will serve the same role for safety analysis that the *Highway Capacity Manual* (HCM) serves for traffic operational analysis. The purpose of the HSM will be to provide the best factual information and tools in a useful form to facilitate roadway planning, design, operations, and maintenance decisions based on explicit consideration of their safety consequences. TRB has formed a Task Force on Development of the Highway Safety Manual to coordinate HSM-related activities.

The emphasis of the HSM will be on the development of quantitative tools. Quantitative tools for the HSM have been developed for two-lane highways by the FHWA, for use in its Interactive Highway Safety Design Model (IHSDM). It is being considered for use in the HSM, along with modifications of that methodology. Efforts are underway to develop quantitative tools for urban and suburban arterials in NCHRP Project 17-26 and for rural multilane highways in NCHRP Project 17-29. These are intended to constitute Part III of the HSM. In addition to the quantitative tools, Part I of the HSM will introduce the Manual and provide an overview of its functions and applications, as well as present some fundamentals of highway safety for the user. Part II will present a summary of knowledge regarding safety affects of various aspects of roadway design and operation, in a form that users can readily apply to their work. Part IV will describe effective techniques for safety management of a roadway system and Part V will present state-of-the-art approaches to evaluation of the safety effectiveness of implemented projects. HSM Parts I and II are being developed in NCHRP Project 17-27 and HSM Parts IV and V are being developed in NCHRP Project 17-34. NCHRP Project 17-36 will assemble these materials and develop the first edition of the HSM in final form for publication.

While the resources to complete and publish the HSM are now in place, an important effort is needed to assure that the HSM is effectively implemented. This will require guidance for highway-agency management on the appropriate application of the HSM, as well as training for engineers and planners on using the HSM. The HSM will provide a major opportunity for advancing the state of practice of highway safety. However, that opportunity will only be fully realized if potential users receive training in the application of the HSM to practical problem solving. The proposed project will develop the needed training materials, design a training course that uses those materials, and recommend a training plan to be coordinated with the release of the first edition of the HSM.

♦ Project 17-40
Safety Workforce Training Development

Research Field:	Traffic
Source:	AASHTO Standing Committee on Highway Traffic Safety
Allocation:	$325,000
NCHRP Staff:	Charles W. Niessner

The field of highway safety draws upon engineering, economics, public law and policy, law enforcement, psychology/human factors, medicine, public health, administration, education, statistics and physics, among others. It is also a relatively new field with the landmark highway safety legislation of 1966 defining the field. Many of the professionals drawn into the field during those early days have entered or are soon entering retirement. The lack of young professionals to replace them is a serious challenge, and the means of recruiting, educating and training future highway safety professionals is lacking.

A workshop organized by AASHTO through the Standing Committee on Highway Traffic Safety, FHWA, and TRB in 2002 more clearly defined the seriousness and critical nature of the problem. At the 2003 TRB Annual meeting, a Joint Subcommittee of Safety Workforce Development was formed to address the issue. To gain a better understanding of the problem, a search/scan of university highway safety education and training programs was conducted. In light of the findings from that scan, the Subcommittee developed a set of "core competencies" for highway safety professionals.

The initial search and scan of university programs substantiated the point raised in the AASHTO workshop and widely held among highway safety professionals: there is a lack of broad-based multidisciplinary safety educational offerings at the advanced undergraduate and graduate level. A more thorough survey of universities found that while there were 6-10 programs with graduate offerings, they were typically a single course and did not represent the depth and breadth of coverage needed for training highway safety professionals.

The core competencies for highway safety professionals are intended to provide a broad framework for educating new safety professionals and training the existing workforce. They represent the fundamental set of knowledge, skills, and abilities needed to effectively function as a professional in highway/traffic safety. As such they are the ground work considered necessary across safety specializations such as engineering, analysis, public policy, road user behavior, injury prevention and control, and safety management.

The objective of this project is to develop training curriculum covering the core competencies and pre-test the curricula in an appropriate setting. The project is proposed in three phases. During Phase 1, story boards will be produced for the entire curricula. These most likely would be a series of modules each corresponding to one core competency. Each core competency has 6-10 learning objectives and the storyboards would detail how those learning objectives will be achieved. At least one module will be developed in this Phase for panel review. In Phase 2, the remaining modules will be developed and completed. Phase 3 will develop an implementation plan and do a single pilot test of the modules.

♦ Project 18-13
Investigation of Fly Ash Properties and Their Effect on the Durability of Concrete

Research Field:	Materials and Construction
Source:	AASHTO Highway Subcommittee on Materials
Allocation:	$900,000
NCHRP Staff:	Amir N. Hanna

During the last twenty years fly ash has gone from being a waste product of coal combustion to an integral part of concrete construction. Also in the same period, increasing demand for fly ash and ever-tightening constraints on stack emissions have created problems with fly ash composition, uniformity and suitability as a concrete mineral admixture. Currently, the use of additives to control emissions is increasing while power plant operations are being modified to decrease emissions. These approaches are being implemented without consideration of potential effects on fly ash.

Coincidentally, during the last two decades there has been an increase in concrete problems with structures and pavements. Cracking of newly constructed bridge decks is a nationally recognized problem, pavements are suffering from finger-spalling during and immediately after joint sawing, and alkali-silica reactivity is occurring in areas that had no prior problems even though the same aggregate sources are being used today as in the past. There is every indication that concrete performance has changed and there is a distinct possibility that some fly ashes may have contributed to this change, though not the sole contributors. It is not realistic or even desirable to consider going back to fly ash-free concrete mixtures but it is imperative that new specifications for fly ash, extending beyond the current provisions of AASHTO M 295 (ASTM C 618) be developed to provide assurance that a given fly ash will perform adequately in a given concrete mixture.

In addition, the strong demand for Class F fly ashes, specifically for alkali-silica reactivity (ASR) mitigation, has led to an increasingly short supply of suitable ash. Industry is addressing this shortage by attempts to beneficiate marginal fly ashes and by blending ash from different sources. Also, industry is challenging the applicability of the current loss on ignition (LOI) limit for fly ashes (5%) by pointing out that the specification is aimed at controlling difficulties with entraining air in fly ash concrete mixtures. Total carbon, as measured indirectly as LOI, does not measure the potential for air problems as only the porous, high surface area carbon, known as activated charcoal, causes problems by adsorbing air entraining agents.

The objectives of this research are to characterize the composition, mineralogy and physical and chemical interactions of all types of fly ashes, including beneficiated and blended ashes, used in typical highway concrete and develop specifications for their use that will insure they are used correctly and facilitate the ongoing use of fly ash in highway construction. Accomplishment of these objectives will require at least the following tasks:

1. Conduct a comprehensive review of the pertinent literature and current research.
2. Conduct a survey of states and provinces to determine what fly ash sources are being utilized in highway construction as well as applicable specification requirements being used by various agencies where they differ from AASHTO M 295.
3. Collect a representative sample cross section of fly ashes, including blended and beneficiated ones, covering the ranges of composition, carbon content, and performance history necessary to elucidate the requirements for reliable performance in concrete.
4. Conduct physical, chemical, and mineralogical analyses on the fly ashes including Rietveld X-ray diffraction, morphological determination of the carbon forms in the fly ash through petrographic examinations and/or TGA analysis, and other appropriate techniques.
5. Conduct a series of physical tests on mortar and concrete specimens to determine the effects of fly ash chemistry and addition rates on setting behavior, permeability, shrinkage, soundness, ASR, sulfate resistance, compressive strength, and other properties using cements that reflect the range of available materials (e.g., Types I, II, III, and V with low and normal alkali).
6. Examine the effects of blending and beneficiation on fly ash composition and uniformity and investigate potential requirements capable of insuring that these materials can be used in the same fashion as existing, untreated fly ash sources.
7. Investigate the role of carbon surface energy and area on air entraining systems and develop or refine testing protocols for determining deleterious carbon content that can be used in conjunction with LOI for specifying fly ashes.
8. Provide recommendations for revising AASHTO M 295 specification requirements for fly ash, depending on source, composition, and concrete mixture components that will clearly define potential usage and restrict inappropriate ashes while minimizing risks with respect to construction and durability issues
9. Prepare and submit a final report summarizing the literature review, research methodology, findings, and conclusions.

♦ Project 18-14
Analysis and Control of Cracking at Ends of Pretensioned Concrete Girders

Research Field:	Materials and Construction
Source:	AASHTO Highway Subcommittee on Bridges and Structures
Allocation:	$300,000
NCHRP Staff:	David B. Beal

Precast, prestressed concrete girders are widely used in the U.S. for bridge construction. Cracks are observed particularly at the ends of a significant number of new large prestressed concrete girders. There have been a variety of reactions to observed web and end cracking including the rejection of girders, debonding strands at the ends, a reduction in permissible prestress force, a reduction in allowable bottom stress at the time of transfer, the injection of sealants in cracks, coating the ends of girders, and even "repair" procedures that include using carbon fiber wraps. The different approaches are having a significant disruptive effect on the industry. Clearly there is not an understanding of the causes of end cracking and what level of end cracking is acceptable or repairable.

With the use of higher strength concrete, deeper beams and significantly higher prestress forces, cracks are becoming more prevalent and in some cases, larger. Web cracks at the ends of girders are usually observed in large prestressed concrete girders and form during or shortly after transfer. The girders are most susceptible when they are young and are being suspended from lifting eye strands embedded near the ends. The cracks typically angle downwards from the end of the member at 5 to 30 degrees, are 0.003-0.006-in. wide, and can be up to a few feet long. Some cracks have been observed up to 0.01-in.

There are several potential causes of end cracking. In the *Precast/Prestressed Concrete Institute Repair Manual*, the potential causes of end cracking are identified to be improper procedures for detensioning (improper sequence or method), shortcomings in design, and problems in production. Under design shortcomings, the relevant possible causes include low concrete strength at release, inadequate vertical tensile reinforcement, excessive prestress or concentration of prestress forces, and excessive number of debonded strands in bottom plane and/or lack of confining stirrups. In production, the relevant potential causes are binding and restraint from forms, shrinkage, and inadequate curing.

The objective of this proposed research project is to develop recommendations to minimize and repair end cracking in prestressed concrete members. The research would have the following tasks: (1) Identify, review, and rank all causes of end region tensile stress in large prestressed concrete girders; (2) For the controllable causes of end region tensile stress, quantify the influence of key factors; (3) Determine the changes in design and production practice that are necessary to reduce end cracking; (4) Gather evidence for defining the width and orientation of cracks that can be ignored, repaired, or should result in the rejection of a girder; and (5) Evaluate the effects of cracks in the final structure.

The expected products of this research project are guidelines for the acceptance and repair of end cracking and recommendations for design and production practice that will eliminate or reduce the likelihood of objectionable end cracking in girders.

♦ Project 18-15
High-Performance/High-Strength Lightweight Concrete for Bridges

Research Field:	Materials and Construction
Source:	Highway Subcommittee on Bridges and Structures
Allocation:	$750,000
NCHRP Staff:	Amir N. Hanna

Lightweight Concrete (LWC) projects have been used in the past for prestressed girders. There is a lack of confidence among bridge engineers in using LWC for bridges. Conventional lightweight concrete has shown some potential problems such as excessive creep deformation, higher camber and higher prestress losses. The durability and the time-dependent behavior of LWC have always been a concern for designers. Use of High Performance LWC (HPLWC) may eliminate most of these concerns. Understanding the behavior of HPLWC will eventually create more confidence in specifying LWC for bridge structures.

In addition, the equation for development lengths in the AASHTO Standard Specifications for Highway Bridges was developed for conventional strength, normal weight concretes. This equation has received a lot of attention in recent years and several revisions have been suggested. Some recent research has also indicated that development length of strand in lightweight concrete members is longer than that in normal weight concrete members. However, review of the literature indicates a lack of information about development length for normal weight concretes with compressive strengths in excess of 70 MPa and lightweight concretes at all strength levels.

When the creep model is developed, it should include an unloading model (long term as a function of days), an early loading model that is a function of hours, as well as the usual long-term loading creep model as a function of days. Parallel shrinkage test should also be conducted. The mix proportions, materials, and additives should be varied for different strengths and material and the creep models should account for these variables.

The *AASHTO LRFD Bridge Construction Specifications* have little mention of lightweight concrete. Bridge construction projects have experienced extremely high heats of hydration, even in sections as thin as one foot. Characteristics affecting heat of hydration for various mixes need to be better understood in order to specify a maximum internal temperature and help develop temperature-control plans for monitoring during construction.

The potential economic benefit of using lightweight high-performance concrete in highway bridge structures is a reduction in the self-weight of the superstructure. This, in turn, reduces the size of girders and substructure members, resulting in smaller foundation size especially in seismic regions. The weight reduction is also particularly important for bridge deck replacement when a higher live load capability may also be required. The weigh reduction also, will facilitate use of larger prefabricated components to facilitate rapid construction technology by reducing shipping and handling weights.

As state DOTs move toward the greater use of high-performance concrete, the need to revise the specifications becomes more urgent. To effectively utilize higher-strength concretes in prestressed concrete girders, larger prestressing forces must be applied to the cross section. This can be accomplished through the use of smaller strand spacings, larger strand sizes, or higher-strength strands. However, before this can be done, information is needed about transfer and development lengths and time-dependent effects associated with high-strength lightweight concrete. Unless this information is provided, the advantages of using high-performance lightweight concrete in bridges will never be fully realized. When heat of hydration is too high, excessive cracking and a leveling off of strength can occur.

The objective of this research is to determine design and construction parameters for successful use of lightweight concrete in large-scale bridge projects. Proposed work will include, but not limited to, the following tasks:

1. Review related literature.
2. Summarize the recent progress that has been done in both research and practical application for lightweight concrete.
3. Conduct the necessary research to study the time-dependent effects of HPLWC.
4. Conduct research to determine transfer and development lengths of prestressing strand in high-strength lightweight concrete. The major parameters of the development and transfer length portion of the investigation are strand size, strand spacing, strand strength, concrete cover, concrete strength, and concrete density.
5. Conduct laboratory and field-testing of prestressed I-girders to determine the strand transfer and development length, and the time-dependent properties of HPLWC and their effect on prestress losses, girder deflection and camber.
6. Conduct laboratory testing or field-monitoring of internal temperatures and concrete properties. Pre-wetting of aggregates, segregation due to vibration, and other critical aspects of workmanship are to be addressed.
7. Recommended modifications to the AASHTO LRFD Bridge Design Specifications and the Bridge Construction Specifications.

♦ **Project 20-71**
A Manual for Methodology of Experimental Design and Analysis

Research Field:	Special Projects
Source:	New York
Allocation:	$250,000
NCHRP Staff:	B. Ray Derr

Experiments play an important role in providing better materials and operational procedures for transportation-related activities. Examples include projects sponsored by NCHRP, state DOTs, and other transportation organizations. Millions of dollars are spent on developing better concrete mixes, asphalt mixes, and other materials. Examples of operational procedures investigated by experimentation include snow and ice operations, roadside maintenance, choice for the equipment configuration, and many others. Comparisons of several measurement methods are also performed using experiments. Examples include nondestructive testing devices, such as a Falling-Weight Deflectometer, pavement density gauges, etc.

Unfortunately, the majority of investigators performing experiments in the transportation field do not use state-of-the-art methodologies of the experimental design. Better use of the current methodologies for designing efficient experiments and for the analysis of the results would save a considerable amount of effort, time, and money in many projects.

It is proposed that a manual be developed that would discuss the methodology of experimental design and analysis. The manual would present state-of-the-art methodologies and give several case studies showing how the experiments should be designed and analyzed in the transportation practice. The manual should be practical with lots of examples geared towards informal and small experiments.

Different areas of application for the experimental methodology often require specific techniques tailored to the needs of experimental program performed. The manual should discuss those techniques and give guidelines (and examples of their use) in different areas such as snow and ice operations, roadside maintenance, materials engineering, etc. The manual should cover factorial designs, randomized block designs, fractional factorial designs, nested designs, response surface methodology, and possibly other techniques as needed for specific areas of application.

♦ Project 20-72
Tools to Aid State DOTs in Workforce Issues

Research Field:	Special Projects
Source:	AASHTO Subcommittee on Personnel and Human Resources
Allocation:	$300,000
NCHRP Staff:	Andrew C. Lemer

The ever-changing workforces of the state DOTs are a constant challenge to manage and to lead. DOTs are seeking ways to develop workforce programs that will help them to recruit, train, and retain their shrinking workforces. Every DOT is trying to develop more programs that address these and other concerns. But program development takes time, effort, and money—the very things that DOTs are short on.

State DOTs are facing the retirement brain drain, the decreasing availability of funds, the reduction of full-time employees, and more short-time employees instead of the longer-term employees they are replacing. These workforce issues cause pressure on DOTs to resolve them, while at the same time they are trying to deliver more products and projects to their customers.

The leaders of the DOTs have asked for assistance and directed AASHTO through the Strategic Plan to help them find programs that will help them in several key areas. The Strategic Plan has just four goals and one of those goals is to “Assist State DOTs with leadership and performance.” Two of the seven objectives under this goal deal with workforce issues. There are a number of key issues of concern to the DOTs, such as (a) core competencies - what are the skills that a DOT must have in order to function, what should be kept if looking at downsizing, outsourcing budget cuts, retirements; (b) downsizing - what should be retained, how to manage a downsizing; (c) outsourcing - what should be kept in-house, how to manage projects on the outside, how to manage competition; (d) recruitment - how to find workers with the necessary skills; (e) retention - once you have employees, how to keep them there; (f) succession planning - training for the future of the agency; (g) in-service training - what training is necessary to improve job skills, improve job satisfaction and help to retain employees. DOTs need to be provided programs, tools, and resources to help them address these issues in making their workforce decisions.

The primary objective of the project is to meet the needs of the member departments as identified by the CEOs in the AASHTO Strategic Plan under Goal 4, by providing DOTs with tools, practical applications, resources, best practices etc. in each of the defined areas. Each DOT should be able to select from a list those items which they want to use. Each defined area should have its own set of resources and materials. This project will entail surveys of DOTs to identify programs, tools and resources that have been developed and that might be used by others. Information on these programs, tools, and resources will be collected and edited for presentation in a form that can be used by DOTs facing workforce issues.

Note: The AASHTO Standing Committee on Research recommends this project should be coordinated with Project 20-24 efforts and that the scope may need to be tightened.

♦ Project 20-73
Best Practices on Accelerating Project Delivery

Research Field:	Special Projects
Source:	AASHTO Standing Committee on Quality
Allocation:	$300,000
NCHRP Staff:	Andrew C. Lemer

The transportation demands of the 21st Century will require state departments of transportation (DOTs) to continually improve their managerial, organizational, and operational effectiveness. One of the main goals articulated in American Association of State Highway and Transportation Officials (AASHTO) 2005-2010 Strategic Plan is to provide state DOTs with a comprehensive framework for improved delivery of all transportation projects. AASHTO's priority is to assist state DOTs in addressing ways and means to improve and accelerate project delivery of all transportation projects from "cradle to grave" (planning and programming through construction and maintenance and operations). This will include addressing environmental review issues, developing a project delivery acceleration tool box, assessing best practices in context sensitive design, and establishing a program to monitor project delivery time frames and impediments. It is not unusual for major projects to take five to seven years in the development phase—planning, environmental assessment, and design—and then three to four years to construct. Many projects take far longer if significant community or environmental issues are involved. Delayed projects exacerbate the social and economic costs of congestion and safety problems.

A good deal of recent research on accelerated project delivery has focused on tools and business practices that can be used to accelerate the completion of different phases of the project implementation process. However, few if any of these efforts address the subject of project acceleration from a holistic perspective—looking at the issue from initial conception to the completion of construction. Most DOTs are organized by functions that correspond to the different phases involved in project implementation: planning; environmental; design; right-of-way acquisition; utility relocation; and construction. These functions are typically grouped into units that are separately administered; an organizational arrangement that requires formal handoffs to take place as projects move from phase to phase. While the need to examine the tools and procedures that have been used to expedite the completion of these individual phases remains, there is a more important need for research of ways in which the different phases can be coordinated in a better and more concurrent manner to eliminate the frequent transition delays that arise as projects progress.

In many states, delays often arise as a result of internal processes or legislative requirements associated with the procurement of consulting services and awarding supplemental work to contractors. Finally, funding for transportation projects is limited and often unpredictable. In addition, it needs to be distributed in an equitable geographic manner across states. As a result, there are macro-optimizations that take place—both formally and informally—to spend the available funds within the required timeframes and avoid focusing an inordinate amount of a DOT's resources in any single location. Projects that need to be accelerated usually are. The question of what would happen if all of a DOT's projects were accelerated needs to be asked. Would funding be exhausted, bringing future work to a halt? Funding constraints dictate that implementation programs be scheduled to accommodate staffing levels and stay within funding limits and schedules. The research will investigate best practices in expediting project delivery in spite of this underlying reality.

The objective of this research is to develop an AASHTO *Guide on Accelerating Project Delivery*. The Guide will address acceleration issues throughout the lifecycle of project delivery from initial conception to completion. The Guide will describe proven acceleration techniques and provide detailed reference information on this body of work. More importantly, it will also fill gaps in the literature, focusing on organizational issues within DOTs and identifying best practices to avoid delays as projects move from one phase of delivery to the next. The Guide will be a comprehensive source of information on the different techniques and approaches that may be used to accelerate project development throughout the entire delivery process. The Guide must be user friendly and provide readers with an appreciation of the time savings that can be gained by using different acceleration techniques successfully. With many acceleration tools in place, the Guide should encourage transportation departments to address the cultural issues underpinning the way in which they conduct business and consider accelerating the delivery of most, if not all of their projects. Accomplishment of the project objective will require at least the following tasks:

1. Identify the different motivations for accelerating project delivery. There are many reasons why transportation owners may wish to accelerate the delivery of highway projects. These may include opening a facility by a critically important milestone date; taking advantage of a funding situation that may expire; minimizing construction period disruptions; avoiding costly stop-and-start situations; or taking advantage of the innate benefits of saving money by moving at a faster pace.
2. Identify constraints to accelerated delivery. It is important to understand the many constraints that state DOTs face in accelerating their work programs.
3. Identify reasonable timeframes—absent significant project-specific barriers—for implementing projects from concept to completion. The goal of this task is to identify reasonable time frames for the delivery of an assortment of "typical" highway projects—from the simple to the complex—for the entire delivery cycle from conception to completion. In addition to identifying timeframes, the analysis should provide an understanding of why these timeframes prevail.
4. Identify measures to improve delivery timeframes within given phases of the project delivery process. This task will involve identifying the different acceleration techniques that can be employed in the main phases of project development: planning; environmental approvals; final design; and right-of-way acquisition, utility relocation and construction.
5. Identify measures to avoid delays between delivery phases and expedite the overall project delivery process from conception to completion.
6. Submit an interim report documenting the work performed in Tasks 1 through 5. For Tasks 4 and 5, the interim report should also identify those acceleration practices for which good documentation already exists. Brief summaries of these practices should be prepared, together with references where further analysis is available. The interim report should then identify gaps which exist within current literature and suggest a plan for prioritizing and filling these voids.
7. Conduct site visits. In order to develop the best possible understanding of the issues involved in accelerating project delivery, the research team will conduct site visits of up to six transportation agencies around the country that have been successful in expediting the delivery of projects from conception to completion.
8. Prepare the AASHTO *Guide on Accelerating Project Delivery*. The guide should provide summaries of well-documented acceleration techniques, together with reference information, and more expansive discussions of those promising practices identified in Task 6 that are less well documented.
9. Prepare Final Report. In addition to the guide, the study team will prepare a final report documenting the entire research effort, with an executive summary and a PowerPoint presentation summarizing the research findings.

Note: The AASHTO Standing Committee on Research recommends that the project should focus on best practices rather than producing an AASHTO guide.

♦ **Project 20-74**
Developing an Asset Management Plan for the Interstate Highway System

Research Field:	Special Projects
Source:	AASHTO Subcommittee on Asset Management
Allocation:	$500,000
NCHRP Staff:	Andrew C. Lemer

Most nations of the world have made significant investments in transportation infrastructure. In the U.S. alone, such investment is estimated to be over $1.75 trillion. However, as this infrastructure is used and exposed to natural environmental forces and suffers from heavier use, its condition deteriorates. In the U.S., in particular, a significant challenge facing national, state, and local officials is how to preserve the functionality of the existing transportation asset base while at the same time funding expansions of the transportation network to handle increasing demands. Although transportation officials often spend considerable time and energy on new roads, transit facilities, airports, and pedestrian and bicycle facilities, by some accounts the nation will be spending more money over the next several decades optimizing the balance between preserving, maintaining, and operating our existing transportation base with the need to build additional facilities.

One of the nation's most significant investments in transportation infrastructure is the Dwight D. Eisenhower System of Interstate and Defense Highways, often referred to as the Interstate Highway System. President Eisenhower signed the Federal-Aid Highway Act in 1956, which began an unprecedented federal investment in surface transportation. It is a remarkable achievement in "accelerated interstate and regional commerce, increased personal mobility, and metropolitan development throughout the United States." (CPR, 2002) The Interstate Highway System is the backbone of the nation's economy and is increasingly critical to "just in time" manufacturing and logistic management. As the world shifts to this global exchange of goods and the United States battles to stay competitive in this changing market, the reliability of the transportation backbone is critical to the U.S.'s economic success.

The Interstate Highway System is reaching its 50th birthday. To sustain the benefits of the Interstate System for future generations, the nation must embark on a systematic effort to monitor the Interstate System and optimize the preservation, upgrading, and timely replacement of highway assets through cost-effective management, programming, and resource allocation decisions. These decisions should be based on universal performance standards for the Interstate System so that limited available funding can be directed to address gaps in performance regardless of geography, infrastructure type (e.g., bridge or pavement), and age.

Asset management is concerned with the entire life-cycle cost of transportation facilities, considering planning, programming, construction, maintenance and operations. Transportation asset management should be policy-driven, with resource allocation decisions based on a well-defined and explicitly stated set of policy goals and objectives reflecting desired system condition, level of service, and safety provided to customers, and tied to economic, community and environmental goals as well. Asset management should be performance-based, with policy objectives translated into system performance measures that are used for both day-to-day and strategic management. Asset management should include analysis of options and tradeoffs in how to allocate resources within and across different types of expenditures (e.g., preventive maintenance, rehabilitation, pavements, bridges, capacity expansion, operations, different modal mixes, safety), based on an analysis of how different allocations will impact achievement of relevant policy objectives. Alternative methods for achieving a desired set of objectives are examined and evaluated. These options are not constrained by established organizational unit boundaries – for example, solving a congestion problem could involve a capacity expansion or an operational improvement (e.g., signal coordination). The best method is selected considering the cost (both initial and long-term) and likely impacts on established performance measures. The limitations posed by realistic funding constraints must be reflected in the range of options and tradeoffs considered.

To be effective, asset management must be based on good information derived from credible and current data. These data may apply to specific functions (e.g., pavement and bridge management, traffic monitoring) or reflect a more integrated, corporate view. Where appropriate, decision support tools are used to provide easy access to needed information, to assist with performance tracking and predictions, and to perform specialized analysis (e.g., optimization, real-time simulation, scenario analysis, life-cycle cost analysis, benefit/cost analysis). Asset management must include monitoring to provide clear accountability and feedback, with performance results reported for both impacts and effectiveness. Feedback on actual performance may influence agency goals and objectives, as well as resource allocation and utilization decisions.

The integration of asset management principles in the decision-making process is prevalent in many countries and a few state and cities throughout the U.S. However, the benefits of asset management have not been demonstrated on a broad scale in the U.S. transportation sector. The national significance of the Interstate Highway System presents an ideal opportunity to demonstrate and apply asset management principles to preserve and maintain this essential infrastructure. This research would develop an asset management process or approach to provide the best information possible to decision makers regarding the maintenance, preservation and operation, and expansion of the Interstate Highway System as a national asset.

The objectives of the research will be to advance asset management principles as the strategic tool for assessing, maintaining, and meeting the future needs of the entire Interstate System; determine a risk allocation process for the Interstate System; identify performance indicators (e.g., smoothness, remaining service life, levels of service, etc.), which are common, consistent and compatible across the entire Interstate System; recommend data to be used in assessing the condition, capacity, and design characteristics and a data-collection and maintenance scheme; develop estimates of economic impacts of degradation of the Interstate System; identify economic analysis and investment performance tools to be used in an asset management program for the Interstate System; and compare relevant U.S. asset management practices with those of other countries, in particular England's trunk system. Accomplishing these objectives will require at least the following tasks:

1. Complete an analysis to determine the benefits of using asset management plans for all segments of the Interstate Highway System. Engage relevant stakeholders in this analysis.
2. Conduct a risk analysis of potential system failure, including identification of failure indicators, review of physical degradation modes and their impact on facility service life, operating efficiencies, and consequences for movement of people and goods on the Interstate System.
3. Identify and use a list of appropriate national asset performance indicators, based on a survey indicators used by states and other countries, data needs for indicators, benefits and drawbacks of a uniform set of indicators for entire Interstate System, potential issues and problems with using the states' existing indicators and processes to normalize information to provide common nationwide measures. Estimate the likely costs to bring the entire Interstate System up to various threshold levels of performance.
4. Develop a data-collection scheme for information necessary to make asset management decisions to maintain the quality and integrity of the various asset components of the Interstate System. The data-collection scheme should include level of detail, frequency and precision of data collection, as well as recommendations on data to be collected to address the indicators identified in previous tasks.
5. Calculate direct and indirect economic impacts of not achieving adequate performance, referring to the results of previous tasks, and considering at least user benefits or costs, growth of economic activity, and environmental and quality of life impacts.
6. Identify tools available to be used in an asset management program for the Interstate System and describe tools that need to be further developed to enable effective management of Interstate System assets.
7. Survey current asset management practices in other countries with a national highway system and prepare a comparative synthesis and assessment of these practice at the national level.
8. Identify obstacles to implementing a national system for management of the Interstate System asset, assessing how states could be encouraged to adopt a national system and discussing tech-

niques for ensuring national standards performance could be achieved.

Note: The AASHTO Standing Committee on Research recommends that this project should be coordinated with NCHRP Project 20-24(52).

♦ **Project 20-75**

Implementing the National Research Council policy study, "Transportation Information Management: A Strategy for the Future"

Research Field:	Special Projects
Source:	Wisconsin, Washington
Allocation:	$200,000
NCHRP Staff:	Christopher J. Hedges

This National Research Council policy study, Project SAIS-P-03-02-A, was sponsored by AASHTO and launched in August 2004, with a final report expected in early 2006. It is the most recent of a series of national studies focusing on the importance of managing information related to the transportation sector. Previous studies addressing this issue date back more than 30 years. Recent studies include: "Value of Information and Information Services," prepared by Volpe National Transportation Systems Center, FHWA-SA-99-038, October 1998; and "Scoping Study for a National Strategic Plan for Transportation Information Management," NCHRP Project No. 20-7/Task 142, June 2003.

The scope of the current National Research Council study is to "…provide strategic advice to the federal government and the states regarding a sustainable administrative structure and funding mechanism for meeting the information services needs of the transportation sector. The committee will define the core services that need to be provided, identify how they should be provided, and suggest options for funding."

It is clear that a concerted effort will be needed to begin implementing this study. A NCHRP project will serve as an appropriate first step in what will be a long-term effort to capitalize on the benefits to be gained—in terms of increased efficiencies, cost savings and quality—through better management of transportation information.

The objective of the research is to begin immediate implementation of recommendations from the policy study. Likely required tasks might include: (1) Develop a detailed business plan for implementing the administrative structure recommended by the Committee. (2) Establish performance measures for evaluating delivery of the core services recommended by the Committee. (3) Engage key U.S. DOT, state DOT, and University Transportation Center personnel in supporting and facilitating implementation of the Committee's recommendations. (4) Develop a prototype website to demonstrate integrated information access and retrieval for a key transportation business need.

♦ **Project 20-76**

Development of Standards and Models of a Disparity/Availability Study Standard for State DOT Disadvantaged Business Enterprise (DBE) Programs

Research Field:	Special Projects
Source:	AASHTO Subcommittee on Civil Rights
Allocation:	$280,000
NCHRP Staff:	Christopher J. Hedges

The U.S. DOT has, since 1987, required that their grantees implement a Disadvantaged Business Enterprise Program (DBE) program based on their Regulations found in 49 CFR Parts 23 and 26. The most current regulations provide states with an annual DBE goal setting methodology. The methodology explains that a Disparity/Availability Study can be used as part of the methodology but does not require its use. A recent 9th Circuit Court of Appeals ruling, however, has made the use of a valid, Disparity/Availability Study as a legal requirement to meet the standards expected by the Court. This requirement has put state DOTs, especially western states located in the 9th Circuit, in a position that will require that they conduct a very expensive disparity study. The current ruling in the 9th Circuit as well as other Appeals Courts that discusses what is needed to maintain the constitutionality of a state's DBE program, demonstrates a trend that a disparity study will be required to justify a state DBE program. There are no guidelines or standards provided to states by the U.S. DOT on the elements of a study that would legally protect state DOTs from a lawsuit. The purpose of this study is to develop standards and a model Disparity Study that can be used by state DOTs to determine the breadth and depth of the need for a Disadvantaged Business Enterprise Program (DBE) in their state. Because of the unique needs of each state, there is a need to have a broad, overarching framework that can be used to guide a contractor's work to develop and conduct a disparity study.

The AASHTO Board of Directors recognized the urgency of receiving guidance on this issue when it passed a Resolution directed at the U.S. DOT at their 2005 Annual meeting. Typical Disparity/Availability studies cost states from $500,000 to over $1 million dollars. This research will provide states with valuable information when writing requests for proposals and well as what information should be gathered and developed. The legal costs to defend federally mandated DBE programs is also costly. This research study is needed to protect states from these types of lawsuits.

The research objective is to provide states with a clear understanding of the legal requirements needed to conduct a valid and legally defensible Disparity/Availability Study. Further, the research will provide states with a model/sample study that can be used in developing a scope of work for a request for proposals, as well as clear steps that should be taken to conduct a study. The specific tasks necessary to achieve the objective include:

A. Conduct a detailed analysis of all court rulings in lawsuits challenging the constitutionality of the U.S. DOT Disadvantaged Business Enterprise Program.
B. Conduct a review of a number of completed studies across the country to identify those studies that should be used as models. Part of the analysis for determining whether a study should be modeled/sampled will be if the study was used successfully in court to justify a DBE program.
C. Include in the above review, the types and quality of data states should maintain and have available for the study.
D. Conduct a review and analysis of all current statistical models and approaches to statistical research including the need for conducting a Regression analysis, theoretical models for defining and determining "capability" of DBEs, and adjustments made to availability.
E. Conduct a detailed analysis of the Federal DBE Regulation (49 CFR Part 26) and in particular Subpart C, 26.45 that discusses the setting of an annual DBE Goal.
F. Conduct a detailed analysis of the costs associated with Disparity/Availability studies. Develop information for states to compare various types of studies and their associated costs.
G. Using the information gathered from the analyses, develop a model Disparity Study that can be used by states in conducting a study themselves or contracting with a consultant to conduct the study.

♦ Project 20-77
Operations Academy

Research Field:	Special Projects
Source:	AASHTO Highway Subcommittee on Systems Operation and Management, AASHTO Special Committee on Transportation Security
Allocation:	$300,000
NCHRP Staff:	B. Ray Derr

Operation of the transportation system is a growing priority for many state DOTs. However, states DOTs are finding a shortage of management and technical staff with appropriate skills and understanding to lead new operations programs. Operations combines elements of numerous disciplines—traffic engineering, intelligent transportation systems, maintenance, emergency operations/incident management, performance measurement, and planning—into an overall approach for increasing the efficiency and safety of the transportation system. Although training exists at the university level and for individual disciplines, there are no training programs for current professionals that address and combine into a single package the breadth of skills needed for operations. This research proposes creation of an operations training academy to address this problem.

This research will create a sustainable transportation operations training academy for state DOT professionals. The training academy is intended to be an intensive and rigorous program that includes testing and certification of participants. The resultant training academy would be administered long-term through AASHTO in partnership with the performing institution, and would be sustained through participant charges. This project will include scoping, content development, and piloting of the training academy.

The following steps are recommended for this project: (1) Convene a panel of state DOT operations directors and professionals to guide course development. (2) Perform background research (possibly including a survey of state DOT operations managers) to help determine the target audience and to assess and prioritize skill sets that should be included in the training academy. (3) Recommend alternative plans for the training academy, including delivery format and content. These may include multiple or a combination of delivery formats. Assess ongoing delivery costs and submit plan for sustaining any options proposed beyond the pilot. (4) Convene panel to select training approach and content. (5) Develop training content. (6) Deliver pilot training academy. (7) Assess the pilot. (8) Work with AASHTO to develop a business plan for ongoing delivery of the training.

It is recommended that this project be administered through AASHTO and that the resultant academy be considered an AASHTO operations training academy. The state DOTs' endorsement through AASHTO will be important for the ultimate success of the academy. In addition, AASHTO, in partnership with the performing institution, will be able to support and sustain the academy beyond the life of the project. AASHTO performs this role with a number of other training programs, most notably the National Transportation Leadership Institute and the New CEO Training.

♦ Project 20-78
Demonstrating the Value of Research

Research Field:	Special Projects
Source:	AASHTO Standing Committee on Research
Allocation:	$250,000
NCHRP Staff:	B. Ray Derr

The nation's transportation system is a complex, dynamic network of physical facilities, operations, and management practices. This system for moving people and goods is essential to domestic productivity, international competitiveness, and quality of life. Transportation accounts for 11 percent of national employment and a substantial portion of the cost of consumer goods. Investments in the transportation system are enormous; it consumes more than $1.3 trillion annually—16 percent of the gross domestic product.

Given today's crowded and deteriorating facilities, transportation professionals must sustain the nation's mobility by finding innovative ways to provide safe and efficient movement of people and goods under more challenging conditions in the years to come.

It is increasingly clear that many of the challenges presented by our transportation system can be met only by innovation based on research. In recent years, the nation has seen rapid innovation in many fields—(e.g., information technology, the space program, national defense, health care, environmental protection, and communications) and of many kinds— (e.g., technological, managerial, and operational). It is clear that the pace of change is so rapid that no industry can be stagnant and remain effective. In the years ahead, it may be technology that exerts the greatest influence on the health of our transportation system. The rapidly changing environment for both freight and passenger travel presents many challenges. Emerging problems, more varied needs, regional differences, deregulation, new regulations, the changing economy, and resource constraints create demands for research, development, and technology transfer. At the same time, evolving computing, control, and communications technologies suggest opportunities for improved products, service, safety, security, and mobility.

At the federal and state levels, research must compete for scarce resources. Justifying these expenditures can be difficult as the benefits of research are often not readily apparent, particularly to the public clamoring for new and improved facilities.

The objective of this project is to develop and demonstrate new approaches and readily usable materials that AASHTO and other organizations can use to demonstrate the value of transportation research to legislators, the public, and the media.

♦ Project 22-24
Development of Verification and Validation Procedures for Computer Simulation Used in Roadside Safety Applications

Research Field:	Design
Source:	AASHTO Technical Committee on Roadside Safety
Allocation:	$300,000
NCHRP Staff:	Charles W. Niessner

Computer simulation is being used to make cost-effective safety decisions on the use of roadside safety hardware and features. However, there are no comprehensive and objective procedures for evaluating the validity of the results of the simulations. Expensive full-scale crash testing is often required to approve modifications to roadside safety devices that have already been fully crash tested. This tool has the potential to progress beyond the development role and into a position where it can be used as an economical and accurate surrogate for full-scale crash testing in the approval process for hardware modifications. It also has the potential to replace some required crash tests, and evaluate impact conditions and installation details that are not currently covered in compliance crash test matrices.

In comparison to full-scale physical testing in accord with *NCHRP Report 350* anyone with access to simulation software and vehicle and roadside features can perform computer simulations without regard to experience or expertise.

Unfortunately, there are no standardized procedures for verifying and validating computer simulations of vehicular impacts with roadside safety features. User agencies, such as FHWA and state DOTs, will soon be faced with requests for safety hardware approval based, at least in part, on finite element (FE) models of one or more of the required full-scale crash tests. Standardized procedures for verification and validation of computer simulation results must be developed to give the approval agencies a tool for assessing the accuracy and credibility of the models used to support such requests.

Historically the performance of roadside safety hardware has been evaluated through full-scale vehicular crash testing. The testing process is typically iterative as design weaknesses and flaws are sequentially discovered and corrected. This type of physical experimentation is extremely expensive and time consuming.

Roadside safety computer simulations involve crashing FE vehicle models into FE roadside appurtenance models. The use of simulation has progressed from modeling historical tests, to supporting design decisions, to leading design efforts using predictive analyses. Effective use of simulation permits design optimization and minimizes the number of crash tests required to achieve acceptable impact performance, thus reducing both the development cost and installed cost of roadside hardware. Additionally, simulation provides a tool for assessing the performance limits of roadside hardware under conditions that cannot be readily tested with full-scale vehicles, such as non-tracking vehicle impacts and the performance of hardware installed on non-level terrain.

Since the FHWA initiated research contracts to develop the first FE models of roadside safety structures in 1995, simulation technology and the role of simulation have continued to evolve. FHWA is now beginning to consider acceptance of simulation in lieu of full-scale crash tests in approval of some modifications to roadside safety systems. They have also used computer simulation results to support policy decisions regarding roadside safety. Yet, little progress has been made toward the key step of developing procedures for objectively establishing the validity of a model or simulation results obtained from its use.

The two corresponding principles that are necessary for assessing the credibility and predictive accuracy of simulations are *verification* and *validation*. *Verification* ensures that the computer model behaves properly according to basic physical laws and properties as allowed by the capabilities of the code from which it is built. *Validation* is the process of assessing and improving the confidence in the usefulness of the computational model for real world applications. In more simple terms, verification is making sure the model works right as far as the computer code (or application) is concerned. Validation is making sure the model truly represents reality, within an acceptable range of tolerance.

Verification and validation must not be done ad hoc, but rather should follow a well-defined procedure that results in reproducible measures of comparison and correlation.

Validation and verification procedures have already been developed for FE models of high consequence systems in other disciplines (e.g., weapons systems, space crafts, nuclear waste packaging, etc). Sandia National Laboratories has developed a *Phenomena Identification and Ranking Table (PIRT)* to assess validity of its high-consequence modeling and simulation. PIRT identifies a set of needed physical phenomena to establish model validation, prioritizes the relative importance of the needed physical phenomena to meeting simulation objectives, and measures the current and future ability of the model to accurately represent the needed physical phenomena. The American Institute of Aeronautics and Astronautics (AIAA) has published a *Guide to Verification and Validation of Computational Fluid Dynamics Simulations (G-077-1998)* to provide standardization in the field of computational fluid dynamics for the purpose of promoting improvement in efficiency and productivity. The American Society of Mechanical Engineers (ASME) has established a committee (PTC 60) on *Verification and Validation in Computational Solid Mechanics*, whose charter is to develop standards for assessing the correctness and credibility of modeling and simulation in computational solid mechanics. This committee plans to have a document available for publication by December 2006. Although the verification and validation procedures described above are applicable to related fields, there are many modeling issues that are quite unique to the roadside safety field. Hence, the existing procedures cannot be adapted directly to the evaluation of computer simulations of roadside safety crash tests.

Particularly relevant to this project are the ongoing activities of the recently established Computational Mechanics/Europe (CM/E) group. CM/E, which exists under the auspices of the European Committee for Standardization (CEN), is engaged in the following activities: defining simulation reporting procedures, defining objective validation procedures, defining requirements for vehicle and barrier models, and defining analyst competency criteria. U.S. entities participating in and monitoring CM/E activities include FHWA, Midwest Roadside Safety Facility (MwRSF), National Crash Analysis Center (NCAC), and Texas Transportation Institute (TTI). The efforts of this group are laying the foundation for the development of objective verification and validation procedures for roadside safety modeling.

The objective of this research is to develop standard procedures and requirements for the verification and validation/quality assurance of computer simulations of roadside safety features. It is intended that these procedures will be used for models of both crash test vehicles and roadside safety devices and the results of these models. The focus of these procedures will be on establishing accuracy, credibility and confidence in computer simulations used to support policy decisions and as the basis for approval of modifications to roadside safety devices that were originally approved with full scale crash testing.

The following tasks may be performed as part of this research: (1) Conduct literature search, (2) Survey current practice, (3) Identify validation metrics for roadside safety applications, (4) Quantify uncertainties (5) Develop verification and validation procedures, and (6) Develop reporting requirements.

♦ **Project 24-31**

AASHTO LRFD Design-Construction Specifications of Shallow Foundations for Highway and Bridge Structures

Research Field:	Soils and Geology
Source:	Massachusetts
Allocation:	$350,000
NCHRP Staff:	David B. Beal

LRFD design specifications for shallow foundations of highway structures are not based on actual data and probabilistic analysis, and are limited to either frictional or cohesive soils. Current analysis methods do not account for uncertainties related to load combinations, site conditions, soil/rock type, and methods of analysis and testing.

There is a need to develop a better understanding of shallow foundations (which account for a large percentage of bridges, retaining walls, and other transportation structures foundation) that will provide for designs with consistent reliability for actual soil characteristics.

The research product will be used to develop design specifications so that safe and efficient shallow foundations of a consistent reliability can be designed and built using state-of-practice ultimate limit state (ULS) methodology. Transportation agencies across the nation will be using these guidelines and specifications. The research proposed will cover all design aspects of shallow foundations and analysis with both ultimate and serviceability limit states for highway and bridge structures.

The objective of this research project is to develop and calibrate procedures and specifications for ULS design of shallow foundations for highway structures. The recommended procedures and specifications shall be suitable for inclusion in the AASHTO LRFD Bridge Design Specifications.

The following tasks may be needed: (1) Address the comprehensive requirements of shallow foundations under ULS (e.g., the combination of inclined and eccentric loading) for soil/rock types and common design methodologies; (2) Develop detailed resistance factors based on a probabilistic approach utilizing extensive databases describing the actual performance of shallow foundations under all states of loading. Loading cases must be either consistent with existing specifications or previous NCHRP studies; (3) Develop the ULS factors to be compatible with the Serviceability Limit State (SLS) requirements as developed and outlined in ongoing NCHRP Project 12-63.

This research will provide comprehensive design-construction specifications of consistent reliability for shallow foundations. The proposed work will help engineers solve existing issues with an efficient and reliable methodology.

♦ Project 24-32

Time Rate of Scour at Wide and Skewed Bridge Piers

Research Field:	Soils and Geology
Source:	AASHTO Technical Committee on Hydrology and Hydraulics
Allocation:	$300,000
NCHRP Staff:	Crawford F. Jencks

Scour depths predicted at very large piers and at long piers skewed to the flood flow are perceived to be excessive. Main channel piers of bridges in navigable rivers and coastal waterways typically are very large to provide sufficient foundation capacity for large spans and to sustain ship impacts. Scour depths predicted by currently accepted equations for these massive piers are in excess of those historically observed. The lack of correlation between observed scour depths and those obtained from predictive equations based on small-scale model studies are likely due to the effects of scale. In particular, the scaling ratio of pier size to sediment size in the model studies is much smaller than that ratio at actual piers. The influence of time is another possible source of the apparent lack of correlation. The duration of flooding during coastal storm surges is limited to the period of the storm surge and may be insufficient for equilibrium scour development. The current equations used to predict scour are based on equilibrium scour conditions that require several days to occur under laboratory conditions.

As skew angle of long piers increases, the effective width perpendicular to the flood flow direction can become very large and create conditions where the effective pier width is large compared to the flow depth. For long slender piers, common practice has been to arbitrarily limit the length to width ratio for selecting the skew angle coefficient, but this limit has never been confirmed experimentally.

To study scour under these pier conditions, wide flumes are required to avoid sidewall and scale effects. Identification of the scour mechanisms that cause scour depths to be substantially less than predicted by existing equations for these flow conditions would translate directly into substantial cost savings for bridge foundations at large piers. The large number of long piers skewed to the approach flow would translate also to substantial cost savings for foundations throughout the United States. The development of a methodology/ies that specifically addresses large piers typical of coast waterways and long piers skewed to the flow direction is needed.

The objectives of this research are: (1) to determine the impact of scale and time on large piers, (2) to develop a method that accounts for the variation of attack angle for long piers, and (3) to develop guidance for the prediction of scour scale effects including the impact of flood flow duration and to develop guidance for the prediction of skew effects for long piers. Accomplishment of the project objectives will require at least the following tasks: Task 1: Critically review the literature from foreign and domestic sources to assess the adequacy and extent of existing information on local scour around piers and to define ranges of experimental parameters that should be investigated. Task 2: Develop a work plan to investigate local scour around large and wide piers. The work plan should include, but not be limited to, experiments designed to assess the effects of scale and flood flow duration on large piers and angle of attack on long piers. Task 3: Submit an interim report containing a review of the literature and a proposed work plan within six months. The interim report must document results of Tasks 1 and 2 and include a set of important parameters to be studied in subsequent experimental work. Task 4: Conduct laboratory experiments to assess the influence of the parameters identified in Task 2 as being important in the process of local scour at large and long bridge piers. Collect data on the time rate of scour development. Tests should be conducted for a comprehensive but typical range of bed materials and flow conditions (clear-water and live-bed conditions). Task 5: Develop a method for predicting the time rate of scour around large piers and equilibrium scour around long piers skewed to the flood flow direction. Test the method of prediction against actual cases of scour around piers. Task 6: Submit a final report that documents the total research effort, tabulates the results of experiments, and summarizes field data. The final report will present the prediction method for scale and time rate, and skew effects, and guidance for its implementation in FHWA HEC 18. Also, the report will examine the accuracy of the method for situations where field data are available.

Note: The AASHTO Standing Committee on Research expects that objectives stated to be accomplished with the funds allocated.